Patient-Specific QA & QA Process

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Outline of Presentation

• QA and QC in RT
• Safety vs. quality
• Patient specific QM program
Learning Objectives

• Describe safety and quality goals in RT
• Describe the benefits of delineating between QA and QC
• Describe approaches to design of patient specific QC procedures
Patient Specific QA

- SRS/SBRT more risky than conventional RT
- How does higher risk translate to patient specific QA/QC procedures?
- Literature and recommendations quite general (generic)
- Combinations of procedures and equipment quite diverse – QA/QC procedures unique
- True understanding of QM principles more important than in almost any other area of RT
Quality\ Safety in RT?

Is this distribution realistic: most patients receive acceptable treatments with a minority being harmed?

Courtesy: TreatSafely
Quality\ Safety in RT?

Or is this more realistic: there’s a continuous distribution from acceptable treatments to harmful treatments?

Courtesy: TreatSafely
Quality\ Safety in RT?


• Stable and well defined processes enable
  – Standardization
  – Quantification
  – Benchmarking
  – Improvements
  – Quality Control

Courtesy: TreatSafely
Quality\ Safety in RT?

Benefit

Uncertainty

Underdose

Target Dose

Overdose

Courtesy: TreatSafely
Reduction Variability

The Goal

1) Timeline
   - Work - Value added
   - Wait - No value

2) Uncertainty

Normative decision theory: Start with efficiency, move to efficacy.

1) Timeline
   - Start with work - Value added
   - Wait - No value

2) Uncertainty
QA and QC in RT

• There are numerous definitions and approaches
• For purposes of this presentation
  – QA: ensuring quality in the process
  – QC: ensuring quality in products
• QC: quality of individual patient treatments
When QC in RT?

- Just before treatment?
- At every step?
- At critical steps?

Consultation → Simulation → Contouring → Planning

Treatment
When QC in RT?

When QC in RT?

- QC potentially resource intensive
- Balance between rework and unnecessary QC
- If QC is not catching anything question its utility
- If QC is catching many things question QA and QM
- Every patient or a sampling of patients
  - In RT tendency is to QA/QC everything
QC possibilities

- Plan of treatment – Peer review
- Simulation – MD, physics, therapy, etc. reviews
- Image registration - MD, physics, dosimetry, etc. reviews
- Contouring - MD, physics, dosimetry, etc. reviews
- Planning - MD, physics, dosimetry, etc. reviews
- Data export - Physics, dosimetry, therapy, etc. reviews
- Data - Physics
- Patient setup - MD, physics, therapy, etc. reviews
- Overall treatment - MD, physics, therapy, peer review, etc.
- …..
When QC in RT?

- It is difficult for individual clinics to prioritize their QA/QC/QM activities if the broader field and community is still struggling with what to prioritize.
- Prioritization requires data.
- Evidence based medicine is becoming mainstream, RT QA/QC need to embrace the same approach.
Example: QA/QC Check Effectiveness

• An analysis of the effectiveness of common QA/QC checks
• IRB between Johns Hopkins University & Washington University
• Both institutions started incident learning systems (ILS) at the same time
• Data:
  o Incident reports: 2007-2011
  o 4,407 reports
  o 292 (7%) “high potential severity”

• PubMed.org search on:
  – (Quality Assurance) AND (Radiation Therapy) AND
    • (IMRT) Results: 463
    • (Chart Checks) Results: 7
    • (Chart Review) - Results: 34
• An order of magnitude difference
How would investors use this data?

Sensitivity (%)

Returns

0 10 20 30 40 50 60 70

0 60 70

Physicists

Therapists

Pre-treatment IMRT QA

Online CT: check by therapist

Online CT: check by physician

In vivo diode measurements

Port films: check by therapist

Port films: check by physician

Timeout by the therapist

Physician weekly chart review

Physician chart review

EPID dosimetry

Port films: check by the therapist

Port films: check by the physician

Online CT: check by physician

Returns
Current IMRTQA Paradigm

“We are pretty good at making sure that we can treat a phantom correctly at ~7:00 pm” – WashU Physicist 2006

1. Transfer patient plan to a QA phantom
   - Dose recalculated (homogeneous) on phantom – any dose calculation errors would not be revealed

2. Perform QA prior to treatment
   - Subsequent data changes/corruption may result in systematic errors for all subsequent patients

3. The volume of data impossible to monitor and verify manually
   - Manual checks do reveal data changes/corruptions, but not reliably

4. The process too laborious with questionable benefits
   - A systematic analysis and redesign demonstrates possibility of a much more robust and automated process
Error spectrum

- **Publicized** - One side of the spectrum, usually large dosimetric errors – NY Times Articles
- **Semi-publicized** – RPC data
  - Approximately 20% of *participating* institutions fail the credentialing test at 7% or 4mm*
  - Approximately 30% fail at 5%*
- **Unpublicized/unnoted** – everyday occurrences
  - “Small” dosimetric errors and geographic misses
  - Suboptimal treatment plans (contouring and dose distributions)
  - Care coordination issues
  - Unnecessary treatment delays

### QM Tools

**Table 2.** Ranking of QM tools based on the effectiveness, in part following the suggestions of ISMP.¹³

<table>
<thead>
<tr>
<th>0. Environment problem correction (Not tool)</th>
<th>4. Independent double check systems and other redundancies</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Sound Control</td>
<td>• Redundant measurement</td>
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<tr>
<td>• Visual Control</td>
<td>• Independent review</td>
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<tr>
<td>• Cleaning</td>
<td>• Operational Checks</td>
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<tr>
<td>• Neatening</td>
<td>• Comparison with standards</td>
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<tr>
<td>• Isolation</td>
<td>• Increase monitoring</td>
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<tr>
<td>• Environmental Design</td>
<td>• Add status check</td>
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<td></td>
<td>• Acceptance test</td>
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<table>
<thead>
<tr>
<th>1. Forcing functions and constraints</th>
<th>5. Rules and policies</th>
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<tbody>
<tr>
<td>• Interlock</td>
<td>• External Audit</td>
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<tr>
<td>• Barriers</td>
<td>• Internal Audit</td>
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<tr>
<td>• Computerized order entry with feedback</td>
<td>• Priority</td>
</tr>
<tr>
<td></td>
<td>• Establishing / Clarify Communication Line</td>
</tr>
<tr>
<td></td>
<td>• Staffing</td>
</tr>
<tr>
<td></td>
<td>• Better Scheduling</td>
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<tr>
<td></td>
<td>• Mandatory Pauses</td>
</tr>
<tr>
<td></td>
<td>• Repair</td>
</tr>
<tr>
<td></td>
<td>• PMI (Preventive Maintenance Inspection)</td>
</tr>
<tr>
<td></td>
<td>• Establish and Perform QC and QA</td>
</tr>
<tr>
<td></td>
<td>(Hardware and Software)</td>
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<table>
<thead>
<tr>
<th>2. Automation and computerization</th>
<th>6. Education and Information</th>
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<tr>
<td>• Bar codes</td>
<td>• Training</td>
</tr>
<tr>
<td>• Automate monitoring</td>
<td>• Experience</td>
</tr>
<tr>
<td>• Computerized verification</td>
<td>• Instruction</td>
</tr>
<tr>
<td>• Computerized order entry</td>
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</table>

<table>
<thead>
<tr>
<th>3. Protocols, standards, and information</th>
<th></th>
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<tbody>
<tr>
<td>• Check off forms</td>
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<tr>
<td>• Establishing Protocol / Clarify Protocol</td>
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<td>• Alarms</td>
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<tr>
<td>• Labels</td>
<td></td>
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<td>• Signs</td>
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<td>• Reduce similarity</td>
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Patient Specific QM Program Focus

• Imaging and target delineation
  – TG66, TG76, TG132
• Treatment planning
• Dosimetry
• Localization on treatment machine
• Treatment delivery
• Overall patient management
Example:
Imaging and Target Delineation
Average Motion and Maximum Intensity Projection (MIP)

4D motion

Time-Average

MIP – Maximum Intensity Projection
Image review and artifacts

Dangers of MIP
Image review and artifacts

Dangers of MIP
Breathing Rate Difference

9 bpm

14 bpm
Breathing Rate Difference (MIP)

9 bpm

14 bpm

9 mm difference
Phase vs. Amplitude

Smaller tumor size on Amplitude-MIP

Green contour: ITV based on Phase-MIP

Yellow contour: ITV based on Amplitude-MIP
CT Dataset Type for Contouring

1. ITV\textsubscript{AllPhases}: GTV on each of 10 respiratory phases and combining these GTVs – Can use for everything

2. ITV\textsubscript{2Phase}: contouring GTV on peak inhale (0% phase) and the peak exhale phase (nominally - 50%) and then combining the two – Generally used for abdomen

3. ITV\textsubscript{MIP}: contouring GTV on MIP with modifications based on physician's visual verification of contours in each respiratory phase – Use for hyperdense tissues with caveats

4. ITV\textsubscript{MinIP}: contouring GTV on MinIP with modification by physician – Use for hypodense tissues with caveats

5. ITV\textsubscript{2M}: combining ITV\textsubscript{MIP} and ITV\textsubscript{MinIP}. – Use for tissues exhibiting hypo and hyper density
a) GTV (green contour), b) ITV_{AllPhases}, c) ITV_{2Phase}, d) ITV_{MIP}, e) ITV_{MinIP} and f) ITV_{2M} - ITV_{MIP} and ITV_{MinIP} contours are as they appear on the intensity projection data set; all others are registered to the 0% phase of the 4D CT data set.

Use of combined maximum and minimum intensity projections to determine internal target volume in 4-dimensional CT scans for hepatic malignancies, Liu et al, Radiation Oncology 2012, 7:11
### Dataset Type for Contouring

Use of combined maximum and minimum intensity projections to determine internal target volume in 4-dimensional CT scans for hepatic malignancies, Liu et al, *Radiation Oncology* 2012, 7:11

<table>
<thead>
<tr>
<th>Patient</th>
<th>( \text{ITV}_{\text{AllPhases}} ) (cm(^3))</th>
<th>( \text{ITV}_{2M} ) (cm(^3))</th>
<th>( \text{ITV}_{2\text{Phase}} ) (cm(^3))</th>
<th>( \text{ITV}_{\text{MinIP}} ) (cm(^3))</th>
<th>( \text{ITV}_{\text{MIP}} ) (cm(^3))</th>
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<td><strong>Mean</strong></td>
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<td><strong>SD</strong></td>
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Multiple Targets

Stats: RML

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<th>ROI Type</th>
<th>ROI</th>
<th>Titl</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>Std. Dev.</th>
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<tr>
<td>BRONC_TREE</td>
<td>RML</td>
<td>1.9</td>
<td>1189.5</td>
<td>428.8</td>
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<tr>
<td>CHEST WALL</td>
<td>RML</td>
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<td>ESOPHAGUS</td>
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<td>GTV RML</td>
<td>RML</td>
<td>5875.4</td>
<td>6374.2</td>
<td>6145.8</td>
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<td>LUNG COMBINED</td>
<td>RML</td>
<td>5.1</td>
<td>6374.2</td>
<td>384.8</td>
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<td>LUNG_L</td>
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<td>PTV_RML540Gy</td>
<td>RML</td>
<td>5673.1</td>
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PTV_RLL 50Gy CI = 0.995 & R50 = 5.4

Stats: RLL

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<th>Titl</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>Std. Dev.</th>
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<td>BRONC_TREE</td>
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<td>1138.1</td>
<td>791.1</td>
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<tr>
<td>ESOPHAGUS</td>
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<td>605.5</td>
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<td>GTV_RLL</td>
<td>RLL</td>
<td>5972.2</td>
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<td>LUNG COMBINED</td>
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</table>

PTV_RMM 54Gy CI = 0.997 & R50 = 4.9
Multiple Targets

- Matching target and Rx during planning
- Matching target and treatment calendar during delivery
- Localization
- Reviewing individual as well as composite plans (dose per fraction and total dose matter)
Summary | Conclusion

- Patient specific QA/QC critical in stereotactic and hypofractionated procedures
- QM program design largely dependent on local medical physicist
- Understanding of technologies, procedures, and critical failure points crucial for safe and quality treatments
References

3. SRT and SBRT: Current practices for QA dosimetry and 3D
8. Use of combined maximum and minimum intensity projections to determine internal target volume in 4-dimensional CT scans for hepatic malignancies, Liu et al, Radiation Oncology 2012, 7:11